AUSTRALIAN RUST STUDIES. VII.

SOME RECENT OBSERVATIONS ON WHEAT STEM RUST IN AUSTRALIA.

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(With Plates iii, iv.)

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Introduction.

It is now generally recognized that the only satisfactory way of controlling wheat stem rust is by the use of resistant varieties. In this country, as elsewhere, the progress of wheat breeding has been such that the disease no longer constitutes a menace in rust liable areas to those growers who cultivate resistant varieties. To a large extent the success of these breeding programmes can be attributed to the fact that in the countries concerned, annual surveys of the stem rust flora have been made. These surveys have two essential objectives. They aim firstly to classify and describe in terms of Stakman's standard set of differential varieties the physiologic races present in a particular area, and secondly, they aim to disclose whether new rusts are arising which are capable of attacking either the resistant varieties under cultivation or those that are valuable as parents.

There is at present considerable information available in the literature on the results to be expected from physiologic race surveys. Most of the data have been collected in the United States and Canada, but from the work of Waterhouse a good deal is known of the cereal rusts present in Australia since 1920. Although the range of variability of *P. graminis tritici* in Australia has been much lower than in North America, rust surveys form an essential component of the local wheat-breeding programmes, and population studies are reported from time to time. Although no report has been published since 1939, in this paper certain facts are summarized concerning recent major changes in the stem rust flora, leaving fuller details to be published later.

RESISTANT PARENTAL MATERIAL.

When the varieties Hope, Webster and Iumillo were imported into this country they formed the main source of resistance to race 34 of stem rust which had first appeared in December 1925 (Waterhouse, 1929). The first two of these varieties—Hope and Webster—were crossed with Federation shortly after they were received in 1926, and Hofed and Fedweb resulted as commercially cultivated stem rust resistant varieties.

About the time these three parents were received, the New South Wales Department of Agriculture imported from Kenya Colony three varieties which have been used widely in crosses. Macindoe (1931) and Waterhouse (1938) have reported on their value as rust resistant parents. They have been carried in University of Sydney Accession Books as Kenya 743, 744 and 745. The New South Wales Department of Agriculture designations for these are C6040, C6041, and C6042 respectively. It has been shown (Watson, 1943) and Watson and Waterhouse (1945) that these three varieties are very different both morphologically and genetically. Each has a single major gene for resistance to race 34 of stem rust in Australia, but each gene is inherited independently of the other two. Kenya 743 and 744 are only partially resistant to flag smut while 745 is practically immune. Differences also occur in grain colour, awn production and several other characters.

Until 1942, the field reaction of all three Kenya wheats was highly satisfactory, and no difficulty was experienced with high temperature effects as reported in Canada (Johnson and Newton, 1941). They all had a further advantage in that their physiological resistance made possible the use of glasshouse tests, since the reactions of seedlings and adult plants were correlated. Seedlings of these three varieties were not identical in their reaction to the same race of rust, and there were also differences in field reactions. Macindoe regarded Kenya 743 as having a greater field resistance, and he concentrated on using this variety in breeding. At the University of Sydney, where seedling reaction to several races was determined, it was found that Kenya 743 was only moderately resistant to race 45. For this reason Kenya 745 was preferred, and of course it possessed flag smut resistance as well. Kenya 744, although it possesses resistance to race 95 of leaf rust, was rejected mainly on account of its very weak straw and lower seedling resistance to race 34. This variety has, however, been used to some extent in Western Australia and Queensland.

Eureka was the first resistant commercial variety to be evolved from the Kenya wheats. Actually Macindoe named two strains, Eureka and Eureka 2, from the cross (Kenya 743 × Florence)F_1 × Dundee. Eureka 2 is distinguished only with difficulty from Eureka, but in general the former strain is later, with a stronger straw and with less tendency to shatter. When released to growers they each appeared to have the full resistance of the Kenya parent (Macindoe 1937).

CULTIVATION OF RESISTANT VARIETIES.

In the north-western areas of New South Wales, the resistant varieties Hofed, Fedweb and the two strains of Eureka made an immediate appeal to growers, since stem rust is a potential serious menace every season in this area. The Eurekas rapidly increased in popularity on account of their rust resistance plus attractive agronomic characters, including ability to produce high yields. From 1938 onwards, increasing acreages were sown to the Eurekas, mainly at the expense of Ford, Nabawa and similar varieties.

Prior to 1941 the resistance of the two Eureka strains was undoubted, for repeated close observations made throughout the wheat belt failed to reveal the presence of stem rust on them. Kenya 743, the resistant parent of Eureka, remained virtually immune in our field tests at Cowra, Glen Innes, Richmond, Tichborne and Gunnedah.

Rust Reactions of Eureka in 1941.

As a result of the strong resistance that Eureka had shown up to this time, it was surprising to find rusted plants of this variety in 1941. In that year Mr. J. A. O'Reilly forwarded rusted Eureka plants collected at Gunnedah and Tamworth. He reported that the attack was not general, only isolated rusted plants being found in these fields of Eureka. The rusted plants Mr. O'Reilly forwarded had well-formed grain, and were accessioned in the University of Sydney varietal collection and have since been carried on.

When the rusts from these collections were received they were used to inoculate seedlings of Kanred, Arnautka and Einkorn. In addition they were put on to seedlings of Eureka from several different sources, as well as on to seedlings from the actual plants that had been rusted in the field. S.U. Culture 334, which was regarded as the standard Australian culture of race 34, was used as a check on seedlings from the rusted plants and on Eureka seedlings from Gunnedah grain. Eureka was known to be highly resistant to this culture both in the seedling and adult plant stage at 65–70°F.

The reactions are given in Table 1.

These tests were carried out during the latter part of November and the early part of December 1941. The reactions of Kanred, Arnautka and Einkorn, which up to this time had been regularly sown to identify the Australian races in the survey work, failed to differentiate between these three rusts. On account of the increased temperature at this time of the year, Eureka from Gunnedah gave a fully susceptible reaction to

TABLE 1.

Rust Reactions Produced by Three Cultures on Several Selected Varieties at Summer Temperatures.

Variety.	Number and Locality of Rust Culture.		
	7150 Tamworth.	7159 Gunnedah.	334 Sydney University.
Kanred	3	3	
Arnautka	3	3	
Einkorn	;	;	
Eureka (seed from Cowra)	3 +	3 +	
,, ,, ,, Gunnedah)	3 +	3 +	3
Eureka 2	3 +	3 +	
Eureka seed from rusted plants 7150 ..	3 +	—	3
,, ,, ,, ,, ,, 7159 ..	—	3 +	3

culture 334. From Table 1 it is clear that the two rusts 7150 and 7159 showed their ability to attack Eureka from Gunnedah and each was capable of attacking seedlings from the plants on which it had been collected. Culture 334 could not be distinguished from them, since at these temperatures all Eureka seedlings tested were susceptible to all three rusts.

Since these tests were unsatisfactory as a means of separating the two new cultures from 334, it was decided to compare the three cultures on seedlings of Eureka at low temperatures during the autumn of 1942. The average glasshouse temperatures had fallen and the reactions given in Table 2 were obtained.

TABLE 2.

Reactions of Eureka to Three Cultures at Low Temperatures.

Variety.	Rust Culture.		
	7150	7159	334
Eureka	; 1	; 1	; 1
Eureka 2	; 1 and 3 +	; 1 and 3 +	; 1 and 3 +

In this test Eureka showed the same resistance that had been characteristic of it in previous years and produced mainly tiny flecks with all cultures. Eureka 2, on the other hand, gave seedlings which proved to be a mixture of resistant and susceptible types. The only conclusion possible from the tests thus far was that Eureka 2 showed heterozygosity for reaction to stem rust. As this could be easily overcome by selection no serious view was taken of it. The cultures 7150 and 7159 were, however, retained as refrigerated stocks for further testing.

Eureka Rust Reactions in 1942.

During the spring of 1942, Mr. O'Reilly again submitted rusted stems of Eureka. He reported that on the property of Mr. A. B. Foxe, "Lyndhurst", Narrabri, Eureka was fairly uniformly infected by rust. One culture, 7316, collected from this field was treated in the usual way and was placed on to seedlings of Kanred, Mindum and Einkorn as well as of Eureka. At this time it was compared with culture 334 and with 7150 and 7159—the two latter being from rusted Eureka in 1941. These tests were carried out in the summer of 1942: the glasshouses temperatures approximated to an average of

80°F. Under these conditions Eureka was susceptible to all four cultures 334, 7150, 7159 and 7316. Johnson and Newton (1941) had already demonstrated that Eureka was susceptible at these temperatures, and indeed it was known that Kenya varieties in general did not retain their resistance when the temperatures were unduly high (Newton et al 1940).

At this stage the four cultures appeared so much alike that it was considered that any differences between them would not allow a reliable separation to be made at these high temperatures and no further tests were made on seedlings during the summer months.

Despite the fact that the glasshouse tests had failed to demonstrate clearly that a new rust had arisen, it was obvious from at least two sets of field data collected late in 1942 that a new rust capable of attacking Eureka was present. The first evidence was from yield trials carried out by the Department of Agriculture on the property of Messrs. White Bros., Boggabri, and already reported by Macindoe (1945). In these tests the sowings had not been made until August and the rust developed on the susceptible varieties to such an extent that they scarcely produced any grain. (See Plate iii.) The yields are given in Table 3.

TABLE 3.
Yields of Grain in 1942 Harvest at Boggabri.

Variety.	Rust Reaction.	Yield, Bushels/acre.
Charter	Resistant.	34
Celebration	,,	25
Yalta	,,	20
Eureka 2	Susceptible.	6
Eureka	,,	3
Ford	,,	1

The second lot of data came from our own field experiments made on the property of Mr. C. H. Beeson, Gunnedah, in the same year. It was found that an entirely new situation had arisen, in that rows of Eureka and Eureka 2 were fully susceptible. It was obviously not due to heterozygosity in the variety, as no plants showed any resistance. It must have been due to the occurrence of a new type of rust.

In these field tests it was usual to sow seed of the three Kenya strains 743, 744 and 745 together with the varieties of Stakman's differential set. For the first time in our observations, Kenya 743 was completely susceptible. Its reaction was indistinguishable from that of Eureka, and it was apparent that the new rust could attack each with equal virulence. In contrast to this, Kenya 744 and 745 were just as resistant as they had been previously.

The occurrence of this new rust at Gunnedah in 1942 gave the first opportunity to assess the value of the other potential stem rust resistant parents. The following were quite resistant; Hope, Hofed, Webster, Fedweb, Gaza, (Bobin × Gaza)F_1 × Bobin [Gabo], (Double Cross × Dundee)F_1 × Dundee [Celebration], (Kenya × Pusa 4)F_1 × Dundee [Yalta], Kenya × Gular [Charter], Dundee × Kenya [Kendee], Hochzucht and Iumillo. The susceptible varieties such as Bencubbin, Ford, Gular and others did not appear to be more heavily rusted than normally, even though they were exposed to an epidemic caused in the main by this new rust. The most striking feature of the field result was the complete susceptibility of Eureka. (See Plates iii and iv.)

Glasshouse Tests since 1943.

During the winter of 1943 when average glasshouse temperatures had fallen to well below 80°F., the refrigerated stock cultures collected on Eureka in 1941 and 1942 were tested on the differential varieties, using culture 334 as a check. In the first instance, cultures 7316 and 334 were each placed separately on to seedlings and adult plants of

Eureka. After incubation the seedlings were kept inside the glasshouse but the adult plants were grown outside.

As mentioned earlier, seedlings of this variety reacted similarly to both rusts during the summer tests. Winter tests at temperatures approximating to 65°F. indicated clearly that these two cultures, 334 and 7316, were very different rusts. Seedlings and adult plants of Eureka when inoculated with culture 334 gave the characteristic fleck and type 1 reactions, but 7316 on this same variety gave only 3 + reactions. These winter tests on plants at two stages of development gave full confirmation of the field results and demonstrated with certainty that a new race of stem rust had arisen capable of attacking Eureka at low temperatures.

In order to determine the particular physiologic race involved in this new attack on Eureka, seedlings of the standard differential set of varieties were inoculated with cultures 334. 7150, 7159 and 7316. The seedlings were raised in an artificially heated room at approximately 75°F. during July, 1943. On the standard set of varieties at those temperatures the four cultures could not be distinguished with certainty, although the reactions on Kubanka and Acme were such as to indicate that possibly separations could be made on these varieties. In the main, however, the reactions were similar to those given by the standard 334 culture.

Although this general similarity existed, there appeared to be certain anomalies in the reaction of some of the differential varieties and it was decided to make a comprehensive analysis of collections taken from various localities. A series was studied consisting of the four collections mentioned above as well as further collections from Gunnedah, Tamworth, Narrabri and Richmond, N.S.W. To these were added collections from Werribee and Longeronong, Victoria, and a collection of race 34 obtained from the United States ("U.S. 34").

These comparisons were carried out over a period of three years, and for purposes of differentiation, Kenya 743 was added to the Stakman list of differential varieties. This was essential, as on the standard set, with the exception of the U.S. 34, the cultures were very similar. The most important difference between them was their ability or inability to attack Kenya 743. As a result of this analysis, which was carried out both during winter and summer, certain differences showed up on these varieties. They can be summarized as follows:

(*a*) *Kubanka*. During the early stages of these critical comparisons it became obvious that the Kubanka reactions were not similar to those previously recorded for culture 334. A check on this rust reaction was made using Kubanka seed from all possible sources. Since all seed lots gave the same result, fresh seed was requested from Dr. E. C. Stakman. However, on plants from the new sceed as well, culture 334 gave either flecks or × reactions or a combination of both instead of the usual 3 + reactions. Repeated comparisons showed that culture 7316 also gave this reaction on Kubanka and was indistinguishable from 334. This variety when tested with the United States race 34 under the same conditions proved fully susceptible. All other rust collections in the series gave Kubanka reactions which were not consistently different from those of 7316 and 334.

(*b*) *Acme*. Cultures from Edgeroi, Narrabri, Richmond, Gunnedah, Tamworth (N.S.W.) and from Longeronong and Werribee (Victoria) were compared on the variety Acme. There was considerable variation, and gradations between high and low reactions on this variety were obtained. Cultures 334, 7150, 7159 were characterized by a mixed reaction, the pustules being mainly of type 3 together with some of type 1. Repeated separations showed that only one rust was producing this mixture. Culture 7316 and several others showing Kenya 743 susceptibility also gave a mixture of type 3 and type 1 pustules, but the majority were of type 1, the overall reaction type being one of greater resistance. Here also attempted separations demonstrated that only one rust was present.

These differences were consistent though slight. They could be decided upon with some confidence when pure cultures were being compared, but mixed cultures could not be determined with any degree of certainty. In view of this, Acme was considered of little use as a variety for differentiation.

(*c*) *Arnautka, Mindum and Spelmar.* It has already been pointed out that these varieties are resistant to culture 334 at low but susceptible at high temperatures (Waterhouse, 1929). All three varieties have reacted similarly in previous studies with Australian collections of rust. During the late winter and early spring these varieties appear to be mixed for rust reactions, giving the × type, but the "mixture" is in fact due to the process of change from resistance to susceptibility. The cultures used in this study, and others collected throughout the wheat belt, all showed this variable reaction on Arnautka, Mindum and Spelmar, and confirmed the earlier work. As a rule it was found that Arnautka showed less variation to these changes in temperature and became susceptible at temperatures at which the other two varieties showed partial resistance. Slight differences were found between certain collections in their ability to attack these varieties, but it was impossible to use them as a safe basis for differentiation. In contrast to this, the United States collection of race 34 gave the characteristic 3 + and 4 reaction on these varieties at all temperatures.

(*d*) *Kenya 743.* The local cultures of rust could be readily placed into two classes on their ability or otherwise to attack Kenya 743. The U.S. race 34 was intermediate in its reaction on this variety, and necrotic areas appeared around the large pustules that developed. This reaction was quite unlike that of 7316. (See Plate iv.)

A typical set of reactions obtained on the varieties is shown in Table 4.

TABLE 4.
Reaction of Differential Varieties to Cultures 334, 7159 and 7316.

Variety.	Typical Reaction to Rust Culture.			
	C.I. Number.	334	7159	7316
Little Club	4066	4	4	4
Marquis	3641	4	4	4
Kanred	5146	3 +	3 +	3 +
Kota	5878	3 +	3 +	3 +
Arnautka	1493	x +, 4	x +, 4	x +, 4
Mindum	5296	x, 4	x, 4	x, 4
Spelmar	6236	x, 4	x, 4	x, 4
Kubanka	2094	; x	; x	; x
Acme	5284	3 and 1	3 and 1	1 and 3
Einkorn	2433	;	;	;
Emmer	3686	;	;	;
Khapli	4013	;	;	;
Kenya 743	—	;	;	3 +
Eureka	—	;	;	3 +

These reactions reveal the tendency for Arnautka to be more severely rusted than Mindum or Spelmar. The Acme reactions are shown as a mixture of pustule type with all three cultures. With 7316 Acme had a predominance of the 1 type reaction while with the other two cultures it showed a greater frequency of the 3 type reaction.

In view of the fact that Kenya 743 at low temperatures served to distinguish the two groups of rusts as represented by 334 and 7316, tests were made to determine whether other varieties would also serve this purpose. It was equally important to find a variety that would separate the 334 and 7316 types at summer temperatures, when the bulk of the rust survey work is done. Over 80 varieties selected from earlier work for their seedling resistance to 334 were tested as seedlings at two different temperatures with cultures 334, 7159 and 7316. The range of temperature in one house was from approximately 60°–65°F. and in the other 70°–75°F. The rust reactions in general were higher at the higher temperatures. It was found, however, that the varieties could be classified according to their reaction type as shown in Tables 5, 6, 7 and 8.

TABLE 5.
Varieties showing Fleck Reactions only when inoculated with Cultures 334, 7159 and 7316.

S.U. No.	Name.	S.U. No.	Name.	S.U. No.	Name.
277	Gaza.	758	Beladi 129.	905	Portugal 24.
745	Kenya.	724	Marquillo.	908	Portugal 60.
752	Beladi 85.	791	Poona.	911	Portugal 86.
753	Beladi 114.	806	Pinet.	913	Portugal 90.
754	Beladi 141.	880	Egypt 7.	916	Portugal 100.
755	Beladi 31.	893	Egypt 50.	945	Morocco 34.
756	Beladi 98.	896	Egypt 59.	1229	Rhodesian.
757	Beladi 132.	904	Portugal 3.		

TABLE 6.
Varieties showing Flecks with some and X Reactions with others of the Three Cultures 334, 7159 and 7316.

S.U. No.	Name.	S.U. No.	Name.
321	Palestine durum.	794	Poona 806.
668	Pinet.	795	Poona 809.
676	Russian.	797	Poona 808.
687	*Trigo africano.*	827	Russian 2995.
717	Vernal Emmer × Iumillo.	832	Russian 1309/2.
726	Nodak.	870	Greece 11.
728	Palestine.	882	Egypt 14.
741	Beladi.	889	Egypt 31.
751	Africano.	891	Egypt 45.
759	Beladi 26.	895	Egypt 56.
760	Bianrollo 20.	906	Portugal 24.
764	Covelle.	914	Portugal 98.
770	Greek 10.	939	Iraq 11.
774	Hordeiforme.	1116	Margerito 11.
790	Nodak.	1227	Hochzucht.
792	Poona 804.		

These varieties classified in Table 6 could probably be regarded as having physiologic resistance to all three cultures. Under the conditions of fluctuating glasshouse temperatures it was found that with any one variety there was a considerable range of

TABLE 7.
Varieties having Moderate Seedling Resistance to the Three Cultures and Designated $3=^{c}$.

S.U. No.	Name.
744	Kenya.
1228	Egypt NA965.
1231	Sabanero.
1238	Rhodesian.
1240	La Estanguela.
1313	Fronteira.
1314	Frondosa.
1315	Supreza.

reaction type. All varieties that appeared to have possibilities for the separation of these cultures were tested during the summer of 1945 but none proved satisfactory as a differential.

Another group of these varieties is shown in Table 7. Included in this list are those lacking the physiologic resistance but nevertheless having some resistance to the cultures.

In Table 8 are shown those varieties which at low temperatures served to differentiate the culture 7316 from 334 and 7159. While these varieties served that purpose, none of them was of any use at high summer temperatures: then they were all completely susceptible.

TABLE 8.
Varieties which at Low Temperatures are Susceptible to Culture 7316 but Resistant to Cultures 334 and 7159.

S.U. No.	Name.
743	Kenya.
1232	Red Egyptian Special.
1233	Red Egyptian.
1234	Birdproof.
1235	Talberg.
1236	Rhodesian.
1237	,,
1239	,,
1311	Eureka.

From these studies it is clear that no variety has been found which could be used to separate the 334 and the 7316 rust types with any degree of certainty during the summer months. Work has been in progress for some time with selections of *T. Timopheevi*, and it is hoped that a satisfactory differential may be found among these.

DESIGNATION OF THE CULTURES.

It has been customary in the past to relate the reactions of any particular rust to those that have been summarized and tabulated by Stakman and Levine (1944) for their differential hosts. Such a procedure has not proved entirely satisfactory as far as the Australian collections are concerned. The difficulty always arises of having some relative standard with which to compare and contrast in detail rusts occurring in different countries. Until some international clearing house is established in which detailed comparisons can be made under identical conditions, we must continue to assume that a good many of the large number of races already described are sufficiently alike to be given the same race number. We must assume too that many of the rusts designated as the same race by independent workers in different countries are sufficiently dissimilar to be given the status of separate races. There is abundant evidence for the existence of biotypes within the described races, and one must not assume that varieties resistant to race 34 in Canada will necessarily give that same reaction to race 34 in Australia. For this reason, from the international viewpoint, the present results from physiologic race surveys must be interpreted with extreme caution.

It is well known now that the breeding of varieties resistant to stem rust is not nearly so complex as might be expected from the large number of races that have been described. One of the reasons for this simplification is that races tend to fall naturally into groups, and one major gene frequently governs resistance to all members of a group. Stakman and Levine in an effort to draw attention to possible affinities between the races, show in their key the races which may be related. For example, they show race 34 to bear some relation to races 63, 77 and 126. Races 56 (which has been recorded in Australia), 125 and 126 are related to race 127. Races 34 and 127 show affinity with race 126.

A consideration of the similarities between these races in the light of the pathogenicity of cultures 334 and 7316 will probably help in the most appropriate designation of these latter cultures. For this reason the respective pathogenicities recorded for all nine are given in Table 9. The reactions of the described races are in this case taken from the table of Stakman and Levine (1944).

TABLE 9.

Reaction of the Differential Varieties to Seven Described Races and to Cultures 334 and 7316.

Race or Culture No.	Little Club.	Marquis.	Kanred.	Kota.	Arnautka.	Mindum.	Spelmar.	Kubanka.	Acme.	Einkorn.	Emmer.	Khapli.
r 34 ..	4 +	4 −	4 −	4 =	4	4 =	4 =	4 ±	3 ++	1 =	0 ;	1 ±
r 56 ..	4	3 +	3 +	3 +	1 =	1 =	1 =	3 +	3 +	1 =	1 =	1 −
r 63 ..	4 +	x ++	4	3 ++	4 +	4 ++	4 +	4 +	4^{n} +	1 =	1 =	0 ;
r 77 ..	4	4	3 =	3 −	3^{c}	3^{c}	3^{c}	4 −	3 +	1 +	x	1
r 125 ..	4 ±	4	4	4	0 ;	0 ;	0 ;	x	4	1 =	0 ;	1 −
r 126 ..	4 =	4 =	3 +	3 +	x ±	x ++	x +	x −	x	1 ±	1 =	1 −
r 127 ..	4 −	4 −	3 ++	3 +	1 =	1 ±	1 =	x	x	0 ;	0 ;	1 −
Culture 334	4	4	3 +	3 +	x +, 4	x, 4	x, 4	;, x	3 and 1	;	;	;
Culture 7316	4	4	3 +	3 +	x +, 4	x, 4	x, 4	;, x	1 and 3	;	;	;

When comparing these reactions with those observed during the course of this study, race 63 can be eliminated from the list since at no time did the present cultures show any tendency to produce an X reaction on Marquis. Similarly all cultures have consistently shown the typical, or type 1, reactions on Emmer. Race 77 can therefore be excluded. In all previous work done here, culture 334 showed the ability to attack vigorously Kubanka, and with its other reactions, was appropriately designated race 34. Much data, accumulated from 1926 to 1941, confirmed this reaction type many times. The results reported here indicate that sometime during or just after 1942 a change occurred in this rust so that it now gives a resistant or at high temperatures a mesothetic reaction on Kubanka. It is apparent that culture 334 can not now be designated as either race 34 or 56. There remain to be considered races 125, 126 and 127.

As indicated earlier, it has been demonstrated that temperature is a very important factor to be considered in the determination of rust reactions (Waterhouse 1929). For this reason determinations have been made at a temperature as close to 70°F. as practicable. This is essential since the Australian culture 334 which up to 1941 has been called race 34 is very sensitive to low temperatures. At temperatures below optimum, Arnautka, Mindum and Spelmar are resistant to this culture, and the reaction type is that of race 56 (Waterhouse 1929). This character of the Australian rust is absent from the United States race 34 (Waterhouse and Watson, 1941).

In the above table showing the reactions of races 125 and 127, Arnautka, Mindum and Spelmar show a resistant reaction. Cultures 334 and 7316 show these reactions only at low temperatures, and as the temperature rises, X reactions change to X+ and finally to the 4 type. As this susceptibility is not typical of either of the races 125 and 127 they can safely be eliminated from the list. When these eliminations have been made, it appears that of the races described by Stakman and Levine, race 126 best fits the reaction types of the cultures that have been examined in these studies.

There are certain anomalies to be explained before giving the Australian cultures this designation. For example, race 126 is tabulated as showing X reactions on Arnautka, Mindum and Spelmar whereas the conditions under which these cultures produced that reaction must be regarded as sub-optimal. The fact that they showed the range from ; to 4 with changing temperatures, whereas the United States race 34 consistently gave 3+ to 4 reactions under the same conditions, seems to warrant their designation as different races. To call these cultures race 126 would necessitate regarding the × reaction as an average of those found with varying temperatures, and this seems a satisfactory compromise.

Another difficulty is that Acme shows a variable reaction to these cultures, type 1 and type 3 pustules being mixed on the same leaf. This reaction is not typical of the mesothetic reaction since the full range of pustule type does not occur. There is no recognized reaction which adequately describes this condition. The X, however, probably describes it as well as any, and this would be a satisfactory classification for all practical purposes. While admitting these two anomalies, it is considered that these cultures can best be called race 126.

In order that some degree of international co-ordination could be arrived at in the description of these cultures, Dr. Stakman kindly agreed to test certain material. In 1947 uredospores of culture 7316 were forwarded to him by air mail. This is identical with 334 on the differential set, except for the Acme reaction. Although he carried out two separate tests, the glasshouse conditions at the time were not good and the following reactions were obtained:

Variety.	Infection type	
Marquis	4 −	4
Reliance	4 −	3 +
Kota	4 −	3 +
Arnautka	4 −c	x +
Mindum	x −	x =
Spelmar	x −	x =
Kubanka	x −	x =
Acme	3, 4-br	3cbr
Einkorn	0; bl	0; bl
Emmer	0; bl	0; bl
Khapli	0;, 1, bl	2 =

br indicates browning.
bl ,, blasting.

He remarked that on account of the browning observed on Acme and the tendency to blast part of the leaf as on Einkorn, Vernal Emmer and Khapli, the rust does not appear to agree with their race 34. The reaction types he gives are very close to race 126 except for that on Acme: the reaction of this variety was complicated by browning.

From the evidence presented here and from the United States results, it appears that culture 334 can now be listed as race 126. Since culture 7316 can only be differentiated satisfactorily from 334 on varieties outside the standard set, it would be convenient and satisfactory to regard the present Australian Eureka-attacking rust as race 126 B.

Comparison of 7316 with the United States Race 34.

Although independent workers engaged in rust survey working in different continents may identify the same race from among their rust collections, it is now well known that they may be dissimilar. Biotypes of existing races can be readily detected by the inclusion of further differentials in the recognized set of 12 varieties. The authors have found (Waterhouse and Watson, 1941) that an American collection of race 34 could be distinguished from an Australian 34 by incorporating into the differential set the varieties Marouani, D5, Nodak, Pinet, Trigo africano, Egypt 75 and Greece 18. Inbred lines of rye also separated these two rusts; and the temperature sensitivity of the Australian 34 was a further important contrasting character.

When the detailed comparative tests were reported in 1941, the 7316 culture had not been collected. About this time, however, Macindoe, working at St. Paul, Minnesota, U.S.A., found that Eureka was susceptible both as seedlings and adult plants in the field to the American culture of race 34 with which he worked. He showed that it was a susceptibility which was not the result of high temperatures as reported by Newton and Johnson (1941). Since this reaction of Eureka in the United States was so unlike that of the New South Wales reaction, consideration was given at an early stage to a possibility that American uredospores may have gained entry to this State and that 7316 was nothing more or less than a biotype of United States race 34. Repeated comparisons of the three cultures 334, 7316 and U.S. 34 were made during the course of the work. Reactions on certain of the differentials were compared more often than others but Table 10 is an average of the reaction types:

TABLE 10.

Comparison of Reactions of Cultures 334, 7316 and U.S. 34.

Variety.	Culture.		
	334	7316	U.S. 34
Little Club ..	4	4	4
Marquis	4	4	3 +
Kanred	3 +	3 +	3 +
Kota	3 +	3 +	3 +
Arnautka	x +, 4	x +, 4	4
Mindum	x, 4	x, 4	4
Spelmar	x, 4	x, 4	4
Kubanka	; x	; x	3 +
Acme	3 and 1	1 and 3	3 +
Emmer	;	;	;
Einkorn	;	;	;
Khapli	;	;	;
Eureka	;	3 +	3^{cn}
Kenya 743 ..	;	3 +	3^{cn}

From these results it is clear that 334 and 7316 are separable only with difficulty on varieties other than Eureka and Kenya 743. Both cultures can be readily distinguished from U.S. 34, however, by their reactions on Kubanka and Acme. Eureka gave a characteristic reaction to all three rusts. It was resistant to 334, fully susceptible to 7316, and intermediate in its reaction to U.S. 34. The large pustules produced by this rust at either low or high temperatures were surrounded by heavy chlorosis and necrosis. (See Plate iv.) In this regard, U.S. 34 was distinct from any of the cultures with which we had worked previously. Apart from the reactions on the differential varieties, the Eureka reactions to these rusts made it unreasonable to suppose that U.S. 34 had taken any part in the alteration of Eureka resistance.

Field Reactions of Eureka in 1946.

When new rust-resistant varieties are released and suffer the fate of Eureka, the accusation may be made that the variety was never fully resistant to rust. The build-up of the 7316 type of inoculum in north-western New South Wales has been such that Eureka is probably the most susceptible variety grown in that area at the present time. Indeed, it is not easy to realize that this variety was one of the most resistant grown in these same areas prior to 1941.

Despite this change in N.S.W., Eureka has maintained its resistance in those areas where only the old type of rust occurs. It has been reported that Eureka is still resistant in Western Australia (Thomas, 1948) and except for one suspicious case in 1947, only the 334 type has been recovered from that State. Our own observations many times confirmed the high degree of resistance which prior to 1941 had been shown by Eureka, and this has been observed again in recent years. At Killara in 1946–47 observation plots of Pusa 4, Cailloux, Gabo, Eureka 2 and Charter were grown. A severe rust attack developed on Pusa 4 and Cailloux and they suffered extensive damage. Despite the widespread occurrence of the 7316 type in the County of Cumberland, Eureka 2, Gabo and Charter remained completely free from rust. In the latter part of the summer season identifications were made of the stem rust present in this plot. Only the 334 type was found. Under the conditions of this test where only the old type of inoculum occurred, Eureka was quite as resistant as it had been when it was first released to growers in 1938.

Origin of the 7316 Type.

In the stem rust areas of North America it is not unusual to find new races of rust arising from time to time. In many cases when such new races have been collected their origin has been correlated with the presence of barberry bushes in the neighbourhood. Since it is well known that new races are produced by the crossing or selfing of certain races on this alternate host, barberry infection is a very satisfactory explanation for the occurrence of pathogenicity changes. It is difficult to advance this suggestion as a means of explaining the origin of the 7316 type in N.S.W. Barberries are known to occur on the tableland areas of this State, but on only one occasion have they been reported as naturally infected by rust (Waterhouse, 1934). While this new 7316 rust could have arisen in this way, it seems on circumstantial evidence most unlikely.

It must be conceded that as far as we know, new cereal rusts are continually arising without the sexual stage on an alternate host. In the case of leaf rust (*P. triticina*), for example, over 100 races have been recorded for this organism (Johnston et al, 1942), but field-infected plants of the alternate host, *Thalictrum* spp., occur only very rarely, and such have never been observed in Australia. For the present it must be assumed that something in addition to hybridization is involved in the formation of new races.

We could conveniently postulate that these new races arise by mutation. However, there is insufficient evidence to explain the process by which these mutations arise. It is known that changes in the characters of fungi can be induced by incorporating chemical substances into the substrate, but to date no such treatment has been possible with the cereal rusts. Mutations both for pathogenicity and for spore colour have been observed here as elsewhere, and their importance in explaining the variability of rust fungi has been shown (Newton and Johnson, 1944). However, the causes responsible are still unknown. Gene mutations may be involved in these changes, or they may be associated with a rearrangement of the dicaryotic nuclei as suggested earlier (Waterhouse, 1929).

As a result of the work by Rodenhiser and Hurd-Karrer (1947) it is clear that hyphal fusions may take place between vegetative (dicaryotic) hyphae, but there is no evidence yet that new races would result. Should contrasting types be brought together by new associations of old nuclei in a dicaryotic mycelium, the "hybrid" may exhibit enhanced pathogenic capabilities. It is probable that even if hyphal fusions do occur within the host plant, a good many of the new combinations would not differ pathogenically from the old. When one of us (I.A.W.) was engaged in extensive race mixing experiments (Watson, 1942) a close watch was kept for the occurrence of new races either by mutation or otherwise, but no changes in pathogenicity were observed. Again, in earlier work by the other author, races 43 and 45 were kept in association for 18 successive generations without any change being discernible. In spite of the difficulty of explaining how a mutation has produced the culture 7316, it seems more likely that it has arisen in this way than by hybridization on the barberry, since this process is so rare in this country.

The mechanism concerned in the formation of these new types is important because it is fundamental to the general problem of variability in fungi, and in this way it is closely associated with breeding for disease resistance. The idea that certain species may act as bridges, enabling pathogenicity to be built up, was initiated at a very early stage of the work on specialization in fungi. However, it was dropped quickly when physiologic races were sorted out and were regarded as stable entities fixed in their pathogenic capabilities.

At the present time there are many happenings which lead to the belief that they are not always very stable. It seems that the work of Reddick and Mills (1938) on *Phytophthora infestans* has revealed certain hazards in the cultivation of varieties with a moderate degree of resistance only. From this work they found that the virulence of the pathogen was increased by successive passages through certain varieties ranging from somewhat resistant through considerably resistant to usually immune. In the field, previously immune varieties became infected as a result of this progressive increase in virulence.

If the result obtained with potatoes could be applied to wheat varieties infected with stem rust, then it is easy to visualize certain varieties acting as satisfactory bridging hosts, since many possess only a moderate field resistance. In 1944 a small experiment was carried out to determine whether in fact seedlings of Eureka could serve as a bridge to build up the virulence of culture 334 so that it could attack Eureka. Four single pustules of this culture were taken, two were increased on Federation and two on Eureka. Those on Federation were kept at low temperatures (60–65°F.) and those on Eureka at high temperatures (75–80° F.) so that the seedlings of this latter variety produced sufficient rust to enable sub-cultures to be made. After the rust had produced each generation of uredospores, those on Federation were transferred back to Federation, those on Eureka back to Eureka. These transfers were continued on the duplicate pots of Eureka and Federation for six successive generations. During the course of the experiment there was no sign of any increase of virulence on Eureka. After the period of six generations, which occupied almost six months, the cultures from Eureka and from Federation were compared at low temperatures on Eureka. Those grown on Eureka for this period showed no greater pathogenicity for this variety than those that had been grown on Federation. The experiment proved of no value in helping to arrive at an explanation of the origin of 7316.

With the limited amount of information available it is possible only to speculate as to the origin of the 7316 culture. There is also no information to help in explaining what has occurred in culture 334. The change in this latter rust is all the more perplexing because not only has the glasshouse culture altered from race 34 to race 126, but a similar change has been shown by all rusts that we have collected in the field in recent years. It is most difficult to visualize any agency so far-reaching in its effects that both glasshouse and field cultures would mutate at about the same time from the old to the new rust. Nevertheless the fact remains that sampling widely in the State gives in the main two rusts. One is of the 334 type, which cannot attack Eureka and which we have called race 126. The other, which is of the 7316 type, occurs on Eureka and we have designated it as race 126B.

The Occurrence of New Rusts in Relation to the Breeding Programme.

When new physiologic races of stem rust arise, it is essential to know how potential parents will react when tested with them. Observations since 1942 have indicated that several of the well-known varieties, such as Hope, Webster, Iumillo, Gaza and Khapli, are fully resistant to the 7316 type in the field. The chief undesirable agronomic characters of Hope, Webster and Gaza have been removed and their resistance factors are available in Hofed, Fedweb and Gabo respectively. In addition to these (Nabawa × Hope) [Warigo] and (Double Cross × Dundee)F_1 × Dundee [Celebration] have had satisfactory field resistance to rust. The other varieties (Kenya × Gular) [Charter], (Kenya × Pusa 4)F_1 × Dundee [Yalta] and (Dundee × Kenya 745) [Kendee] have all shown resistance to all local races, both as seedlings and as adult plants. While the seedlings of these latter varieties have reacted similarly to 7316, they do not all behave alike in the field. On the basis of the 1–6 classification they could be ranked thus:

Charter	1
Kendee	1–2
Yalta	2–3

Eureka for comparison would be 5–6. Yalta is characterized by showing in the field some plants typical of class 4, and this variety seems least resistant of those developed in recent years.

The three varieties Charter, Kendee and Yalta have shown no field complications resulting from the effects of high temperatures, and it is felt that considerable confidence can be placed in the Kenya varieties as rust-resistant parents under Australian conditions. It is, of course, to be expected that certain environments will be found in which their resistance will break down. In 1942 a severe attack of downy mildew (*Sclerospora macrospora*) in certain of the resistant varieties at Tichborne was associated with complete susceptibility to the 334 type of rust. Heads and stems of the varieties so affected are shown in Plate iv. The exact nature of the interaction between host and pathogen is not known, but it is well established that infection by one disease may lead to increased susceptibility to a second disease.

As mentioned earlier, the breeding work in this State has involved extensive use of the Kenya varieties, and the three designated as 743, 744 and 745, which were the first available here, have been used most. Since the first introductions were made, further samples from Kenya have been received. In addition, Dr. Margaret Newton forwarded seed of a comprehensive list of the strains they had studied. Included with this group was also seed of "McMurachy's Selection".

These latest Kenya strains have been tested extensively with cultures 334 and 7316 in the glasshouse: the reactions are given in Table 11.

Prior to the occurrence of the 7316 type in 1941–2, these Kenya varieties appeared to provide a wealth of stem rust resistant material. Nothing was known of the genetic relationships between them except that Kenya 743, 744 and 745 each had independent factors for resistance. The arrival of the 7316 type has, as the results in Table 11 show, completely changed that position, and the majority of the Kenya strains must now be regarded as susceptible to rust in this country. They can be divided clearly into two groups, those that are resistant to both 334 and 7316 types and those that are resistant only to the 334. A good many of these Kenya strains were received without names, so that they can only be identified by their Sydney University Accession Number. In certain cases these numbers can be linked with a Rust Laboratory Accession number. Among the varieties listed, "McMurachy's Selection" appears to be susceptible to 7316 and it segregated for resistance to culture 334. Kenya 117A, which has been found resistant to race 15B in the United States (Loegering, 1944), was resistant to culture 7316.

Culture 334 was used to inoculate F_2 plants of several crosses designed to get some information on the relationship of the resistance genes present in these Kenya varieties. Some of them were crossed among themselves and some were crossed with a Dundee × Kenya 745 selection known to have inherited the resistant gene from Kenya 745. As would be expected, certain crosses showed segregation for susceptibility in F_2, others did not. If no segregation was obtained in several hundred plants, it was taken as good evidence that the two parents had the same factor.

The following crosses did not show any segregation in F_2:

Kenya 743 × Kenya 1037.
Kenya 743 × Kenya 1304 (RL1373) (Minn. 2693).
Kenya 743 × Sweden 1230.
Kenya 745 × Kenya 1035.
Kenya 745 × Kenya 1049 (RL I/35-2).
Kenya 745 × Kenya 1053.
Kenya 1034 × Kenya 1037.
Kenya 1034 × Kenya 1304 (RL1373).
Kenya 1035 × Kenya 745.
Kenya 1035 × Kenya 1053.
Kenya 1037 × Kenya 743.
Kenya 1049 × Kenya 745.
Kenya 1049 × Kenya 1053.
Kenya 1053 × Kenya 745.
Kenya 1053 × Kenya 1035.
Rhodesian 1229 × Kenya 745.
Kenya 1304 (RL1373) × Eureka 1311.
(Kenya × Gular) [Charter] 1345 × Kenya 745.
(Kenya × Gular) [Charter] 1345 × Kenya 1053.
(Gullen × Gaza)F_1 × Gullen 1368 × Kenya 745.
Gabo × Kenya 745.
Gabo × Kendee.
Kendee × Gabo.

TABLE 11.

Seedling Reactions of a Selected Group of Kenya Varieties and "McMurachy's Selection" to Cultures 334 and 7316 at Temperatures of 65–70° F.

S.U. Accession No.	Name of Variety or Designation Given by Other Workers.	Reaction to 334	Reaction to 7316
743	C6040	;	3 +
744	C6041	3 =^{c}	3 =^{c}
745	C6042	;	;
1034		;	3 +
1035		;	;
1037		;	3 +
1049		;	;
1053		;	;
1304	RL1373	;	3 +
1347	117A	;	;
1348	291 J 1A 1	;	
1349	291 J 1B 1	Seg.	3 +
1350	291 J 1 I 1	;	3 +
1351	192 Q 2A (L)	;	3 =
1452	RL I/513	Seg.	3 +
1453	RL I/40–32	;	3 +
1454	RL I/40–33	3 =^{c}	3 =^{c}
1455	RL I/40–34	Seg.	;
1456	RL1387 C9906	;	3
1457	RL1388 C9965	;	3 +
1458	RL1356 C9968	;	3
1459	RL I/40–35 C9968	;	3
1460	RL1352 C10852	;	;
1461	RL I/40–36 C10854	;	;
1462	RL1379 C10857	;	3 +
1463	RL I/40–37 C10857	;	3 +
1464	RL I/40–39 C10860	;	3
1465	RL I/40–40 C10861	;	3
1466	RL I/40–41 C10862	;	3 +
1467	RL1362 C10862	;	3 +
1468	RL1361 C10863	;	;
1469	RL I/40–42 C10864	;	;
1470	RL1370 C10865	;	3
1471	RL I/40–43 C10865	;	3
1472	RL1358 C10866	;	3 +
1473	RL I/40–44 C10866	;	3
1474	RL I/40–45	;	3
1475	RL I/40–46	;, 1	3 +
1476	RL I/35–2	;, 1	; 1
1477	112A RL I/35–4	;, 1	3
1478	122.D.I.T.(L) Minn. 2693 RL1373	;	3 +
1479	117E.16.B.1 ,, 2694 RL1374	;	3 +
1480	117B.5.B.2 ,, 2695 RL1375	;, 1 +	3 +
1481	117K.16A(L) ,, 2697 RL1376	; 3 –^{c}	3 +
1482	117 1.5F(L) ,, 2696 RL1377	; 3 –	3 +
1483	112E 19 J(L) RL1873	; 1 +	
1484	60B12 B 16(L) RL I/34–3	2 =	;
1485	112B (15) L RL I/34–5	; 1	3 +
1486	131 C 5.E RL I/34–2	;	3
1487	58F (L.1) RL I/34–4	; 3 – 3 +	3 +
1488	McMurachy's Selection RL1313	Seg.	3 +

Segregations were found in these crosses:

Kenya 743 × Kenya 1053.
Kenya 743 × Gabo.
Kenya 744 × Kenya 743
Kenya 744 × Kenya 745.
Kenya 744 × Kenya 1035.
Kenya 744 × Kenya 1049 (RL I/35-2).

Kenya 744 × Kenya 1053.
Kenya 744 × Rhodesian 1238.
Kenya 744 × Kenya 1349 291 J 1B 1.
Kenya 744 × Kenya 1351 192 Q 2A(L).
(Federation × Kenya 745) × Kenya 743.
Kenya 745 × Rhodesian 1238.
Kenya 745 × Kenya 1349 291 J 1B 1.
Kenya 745 × Kenya 1351 192 Q 2A(L).
(Federation × Kenya 745) × Sweden 1230.
Kenya 1035 × Kenya 744.
Kenya 1037 × Kenya 745.
Kenya 1037 × Kenya 1035.
Kenya 1037 × Kenya 1049.
Kenya 1049 × Kenya 744.
Kenya 1049 × Rhodesian 1238.
Kenya 1053 × Kenya 744.
Kenya 1053 × Rhodesian 1238.
Rhodesian 1229 × Kenya 744.
Rhodesian 1238 × Kenya 744.
Rhodesian 1238 × Kenya 745.
Kēnya 1034 × Kenya 745.
(Kenya × Gular) [Charter] 1345 × Kenya 744.
Kenya 117A 1347 × Kenya 744.
Kenya 117A 1347 × Kenya 745.
Kenya 1349 × Kenya 744.
Kenya 1349 × Kenya 745.
Kenya 1350 × Kenya 744.
Kenya 1350 × Kenya 745.
Kenya 1351 × Kenya 744.
Kenya 1351 × Kenya 745.
(Gullen × Gaza)F_1 × Gullen 1368 × Kenya 743.
(Gullen × Gaza)F_1 × Gullen 1368 × Kenya 744.

In considering the group of crosses in which no segregation was observed, it appears that two series of varieties are represented. The first series contains Kenya 743 and its related types. Kenya 1304 (RL1373, Minn. 2693), which, as shown in Table 11, gave the same seedling reaction as Kenya 743, apparently has the same gene. Sweden 1230 behaves similarly and, as would be expected, Eureka 1311 belongs in a group with 743. Two other strains, accessioned as 1034 and 1037, both have a single factor for resistance to culture 334 and apparently in each this is the 743 gene. It is obvious that no variety in this group is of any value in contributing to the problem of rust resistance in this State.

The second series contains the variety Kenya 745 and those genetically similar to it. Three strains, Kenya 1035, 1049 and 1053, behave in a way similar to 745. Each has a major gene for resistance, and crosses between these varieties and Kenya 745 give F_2 plants which are all resistant. Of the more recently developed varieties, we have found that Charter and Yalta when crossed with Kenya 745 give F_2 plants which are all persistent. It would appear from this that the two varieties were derived from Kenya 745 as a common ancestor. Kenya 744, which gives segregation when crossed with members of the above groups, is so far placed alone in a third class.

It is of some interest to find that when Gabo and Kendee are crossed, no segregation for rust reaction occurs. Crosses with Gabo and either Kenya 743 or 744 both give in F_2 approximately one plant in 16 that is susceptible. As a result of observations on many thousands of plants of resistant selections of (Bobin × Gaza)F_1 × Bobin crossed with Dundee × Kenya 745, it appears that the single major gene for resistance inherited from Gaza (*T. durum*) is allelic to the one present in Kenya 745.

So far it has not been possible to put the other rust resistant varieties Hofed, Fedweb, Warigo and Celebration into their respective groups, but at least it can be said that Hofed × Eureka crosses show segregations in F_2 and later generations. This is confirmed by the United States workers (Ausemus, 1944), as RL 1373 × Hope showed segregation in F_2. Ausemus also reports segregation in crosses between RL 1373 and Thatcher. This probably means that the Australian variety Celebration would also give this segregation for susceptibility in crosses with RL 1373, Kenya 743 or Eureka.

A considerable amount of work remains to be done on the available genes for resistance to stem rust in Australia, particularly since the advent of culture 7316. All the varieties belonging to the Kenya 745 group are still valuable parents. In addition, Hofed, Fedweb, Celebration and certain (Timopheevi × Steinwedel) selections continue to be very resistant in the field. Many of the varieties shown in Tables 5 and 6 will, no doubt, be of some importance, too, but as yet insufficient data are available dealing with their behaviour to rust in the field.

If we consider the problem of breeding for rust resistance here in the light of American experience with race 15B, the number of varieties available as potential parents is greatly reduced. This biotype of race 15 is differentiated by its ability to attack Rival, but many other varieties are also susceptible to it. According to Ausemus (1944), Hope, Thatcher and (*T. Timopheevi* × Steinwedel) S990 have been susceptible to this biotype both in the seedling and mature plant stage under controlled experimental conditions. He reports further that two Kenya spring wheats, Kenya 58 and 117A, are highly resistant to it, and Red Egyptian is moderately resistant. Da Silva (1947), working at St. Paul, Minn., found Kenya 58 to range from susceptible to moderately susceptible. Sydney University tests on seedlings of K58, 117A and Red Egyptian with 7316 indicate that of the three, only 117A is resistant. For this reason it appears to be a variety of considerable potential value as a source of resistance. Nothing is known yet of the mode of inheritance of its resistance to 7316, but it is a variety quite distinct from 743, 744 and 745, and as well gives a vigorous F_1 in crosses with Khapli Emmer. Apparently its gene is not allelic with that of Kenya 744 or 745, as in crosses with these varieties, susceptible plants have been obtained in the F_2 generation.

The incidence of race 15B in the United States has necessitated an intensive search for varietal resistance. In their present breeding programmes, the aim is to retain resistances to stem rust now available, and wherever possible incorporate resistance to new races. By this means it is hoped to solve new rust problems soon after they arise. This line of approach is being followed to some extent here in that we have added to Eureka the rust resistance of Gabo by back-crossing. Our present policy, however, is to take certain of the very desirable commercial varieties and derive strains from them which are at least morphologically indistinguishable but which have derived their rust resistance from a different source. Eureka and Gabo may be used to illustrate this.

Eureka is a very desirable variety agronomically, and, as mentioned previously, its popularity increased rapidly following its release in 1938. It now lacks resistance to rust. Crosses such as the following have been made or will be made in the near future: Eureka × Gabo, Eureka × Hofed, Eureka × 117A, Eureka × (*T. Timopheevi* × Steinwedel). The resistant progeny from each of the crosses will be backcrossed to Eureka so that most of its genotype will be recovered. In the end a number of different strains closely resembling Eureka will be derived from these backcrossings. They should be practically indistinguishable except that their resistance in each case is due to a different source. One strain, say the (Gabo × Eureka)^4 would, for the time being, be released to growers since we have that in a fairly advanced stage. The others would be retained in the varietal collection and tested immediately a change in the rust flora occurs. If a new race of rust should arise, it is most unlikely that all derived strains will be susceptible. One or other of those resistant both to the old and the new rust would then be immediately increased for distribution. No extensive yield tests should be necessary since the yielding ability will approximate that of Eureka.

Much the same policy is being followed with Gabo. This variety is also very satisfactory commercially, and in the past few seasons has given some phenomenal yields in the north-west of N.S.W. It is also highly resistant to stem rust. As shown above, Gabo has the gene for resistance allelic to the one in Kendee, and this in turn is allelic to that present in Charter and Yalta. It appears likely that should a new strain of rust arise capable of attacking Charter, then Kendee, Gabo and Yalta will also be susceptible. Since Gabo has proved such a high yielding variety, it is considered that other strains, very similar to it but with a range of genic material for rust resistance, should be available. Should a new rust arise against which the Gabo gene is not effective, then one or other of the other genes that have been added to the derived strains would contribute the necessary resistance.

In obtaining the new strains, where possible the technique for combining resistances suggested by Macindoe (1948) will be used. If this is not possible—and it may not be with varieties such as 117A—it is proposed to derive a susceptible strain of Gabo and add the various resistances to it by crosses with the appropriate varieties mentioned above. As with the Eureka strains, those derived from Gabo would be retained until it was necessary to release them.

The essential difference between this approach and that suggested by Ausemus is that the end products will possess in the main only one or two major factors for resistance. It is probable that with the fewer genes they will individually not be resistant to such a wide variety of rust types, but collectively their resistance should be rather comprehensive. It is not possible to breed specifically against new races until they arise, but it is expected that the procedure outlined above will give material showing some resistance to new strains. It is fortunate that at the present time the resistant material available to the Australian wheat breeder still offers a fairly wide choice, and this will probably be the case until something like race 15B arrives. Until then some progress could be made by having resistant hybrid lines tested in the United States for their reaction to the more virulent races there. Preparations must be made, however, for the possible occurrence of races here more pathogenic than any yet recorded elsewhere.

Summary.

During the period 1941–42 a new culture of stem rust arose in New South Wales capable of attacking the variety Eureka. At about this time a change also occurred in the race 34 which was so widespread throughout Australia. There are now present in most parts of the country mainly two races of stem rust; one cannot attack Eureka and is listed as race 126; the other is very similar to it, except that Eureka is susceptible. This is regarded as a biotype of race 126 and listed as race 126B. Since 1942 the old rust which for many years was regarded as race 34 has not been collected and it is considered that race 126B represents a mutation from race 34. In the absence of race 126B, Eureka is still a highly resistant variety. Several varieties are very resistant to races 126 and 126B. Most of the Kenya varieties are susceptible, but one, namely 117A, is of special interest in that it is resistant to race 15B in the United States as well as to races 126 and 126B here.

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References.

Ausemus, E. R., 1944.—Breeding for Stem Rust Resistance in Spring Wheat. Rep. Mill. Baking Mtg. 7th Hard Spring Wheat Conf., Minneapolis, Minn., pp. 27. Mimeographed.

Da Silva, A. R., 1947.—Estudos Preliminares Para a Producao de Variedades de Trigo Resistentes as Ferrugens no Brasil. Bol. Serv. Nacion. Pesq. Agron., No. 1, pp. 53.

Johnson, T., and Newton, Margaret, 1941.—The Effect of High Temperature on the Stem Rust Resistance of Wheat Varieties. *Canad. J. Res.*, 19, 438-445.

Johnston, C. O., Humphrey, H. B., Caldwell, R. M., and Compton, L. R. F., 1942.—Third Revision of the International Register of Physiologic Races of Leaf Rust of Wheat.

Loegering, W. Q., 1944.—Stem and Leaf Rust in Relation to Wheat Breeding. Three Greenhouse Inoculations with Stem Rust. Rep. Mill. Baking Mtg. 7th Hard Spring Wheat Conf., Minneapolis, Minn., pp. 27. Mimeographed.

Macindoe, S. L., 1931.—Stem Rust of Wheat. Observations at Glen Innes during 1930-31 Season. *Agric. Gaz. N.S.W.*, 42, 475-484.

————, 1937.—The New Era in Breeding Wheats Resistant to Stem Rust. *Jour. Aust. Inst. Agric. Sc.*, 3, 25-31.

————, 1945.—New Stem Rust Resistant Wheats to Replace Eureka. *Agric. Gaz. N.S.W.*, 56, 530-531.

MACINDOE, S. L., 1948.—The Nature and Inheritance of Resistance to Stem Rust of Wheat, *Puccinia graminis tritici*, possessed by Several Parents. *N.S.W. Dept. Agric. Science Bull.* No. 69.

NEWTON, MARGARET, JOHNSON, T., and PETURSON, B., 1940.—Seedling Reactions of Wheat Varieties to Stem Rust and Leaf Rust and of Oat Varieties to Stem Rust and Crown Rust. *Canad. J. Res.*, 18, 489-506.

————, 1946.—Physiologic Races of *Puccinia graminis tritici* in Canada, 1919 to 1944. *Canad. J. Res.*, 24, 26-38.

REDDICK, D., and MILLS, W. D., 1938.—Building up Virulence in *Phytophthora infestans*. *Amer. Potato Jour.*, 15, 29-34.

RODENHISER, H. A., and HURD-KARRER, ANNIE M., 1947.—Evidence of Fusion Bodies from Urediospore Germ Tubes of Cereal Rusts on Nutrient Solution Agar. *Phytopath.*, 37 744-756.

STAKMAN, E. C., LEVINE, M. N., and LOEGERING, W. Q., 1944.—Identification of Physiologic Races of *Puccinia graminis tritici*. *Paper 2148, Scientific Journal Series, Minn. Agr. Exp. Station.*

THOMAS, I., 1948.—Wheat Variety Trials. *J. Agric. West. Aust.*, 25, 84-94.

WATERHOUSE, W. L., 1929.—Australian Rust Studies I. PROC. LINN. SOC. N.S.W., liv, 615-680.

————, 1934.—Australian Rust Studies IV. Natural Infection of Barberries by Black Stem Rust in Australia. PROC. LINN. SOC. N.S.W., lix, 16-18.

————, 1938.—Some Aspects of Problems in Breeding for Rust Resistance in Cereals. *J. Roy. Soc. N.S.W.*, 72, 7-54.

————, and WATSON, I. A., 1941.—Australian Rust Studies VI. Comparative Studies of Biotypes of Race 34 of *Puccinia graminis tritici*. PROC. LINN. SOC. N.S.W., lxvi, 269-275.

WATSON, I. A., 1942.—The Development of Physiologic Races of *Puccinia graminis tritici* Singly and in Association with Others. PROC. LINN. SOC. N.S.W., lxvii, 294-312.

————, 1943.—Inheritance Studies with Kenya Varieties of *Triticum vulgare* Vill. PROC. LINN. SOC. N.S.W., lxviii, 72-90.

————, and WATERHOUSE, W. L., 1945.—A Third Factor for Resistance to *Puccinia graminis tritici*. *Nature*, 155, 205.

EXPLANATION OF PLATES.

PLATE III.

A. Typical straw of eight different varieties of wheat showing the effects of stem rust at Gunnedah, 1942. 1. Ford. 2. Eureka. 3. Kenya 743. 4. Kenya 744. 5. Kenya 745. 6. Kendee. 7. Fedweb. 8. Gabo.

B. Typical grain showing the effects of stem rust at Gunnedah, 1942. The same number of grains was photographed in each case. 1. Ford. 2. Eureka. 3. Fedweb. 4. Gabo.

PLATE IV.

A. Typical straw showing the effects of stem rust on three varieties at Badgery's Creek, 1942. 1. Federation. 2. Eureka. 3. Kenya 745. Eureka, which was formerly resistant, is now as susceptible as Federation, whilst Kenya 745 maintains its resistance.

B. Above are shown normal healthy heads to the right in each pair, and distorted heads caused by *Sclerospora macrospora* to the left in each pair of 1. Kendee, and 2. Gabo. Below are shown stems of these varieties showing how attack by *S. macrospora* now renders them susceptible to stem rust. Grown at Tichborne, 1942.

C. A comparison between leaves of Eureka inoculated with the new race styled r. 126B(1.) and similar leaves inoculated with U.S.A. r. 34(2.). In each pair of leaves the left shows the upper and the right the lower surface. (Nat. size × 2.)